Date: 22/10/2021

Q1. The maximum amplitude of an A.M. wave is found to be 15 V while its minimum amplitude is found to be 3 V. What is the modulation index?

Q2. Would sky waves be suitable for transmission of TV signals of 60 MHz frequency?

Q3. Two waves *A* and *B* of frequencies 2 MHz and 3 MHz, respectively are beamed in the same direction for communication via sky wave. Which one of these is likely to travel longer distance in the ionosphere before suffering total internal reflection?

Q4. Compute the *LC* product of a tuned amplifier circuit required to generate a carrier wave of 1 MHz for amplitude modulation.

Q5. Why is a AM signal likely to be more noisy than a FM signal upon transmission through a channel?

Q6. Which of the following would produce analog signals and which would produce digital signals?

(a) A vibrating tuning fork.

(b) Musical sound due to a vibrating sitar string.

(c) Light pulse.

(d) Output of NAND gate.

Q7. A TV transmission tower antenna is at a height of 20 m. How much service area can it cover if the receiving antenna is (a) at ground level, (b) at a height of 25 m? Calculate the percentage increase in area covered in case (ii) relative to case (i).

Q8. On radiating (sending out) an AM modulated signal, the total radiated power is due to energy carried by ω_c, $\omega_c - \omega_m$ & $\omega_c + \omega_m$. Suggest ways to minimise cost of radiation without compromising on information.

Q9. Figure shows a communication system. What is the output power when input signal is of 1.01 mW? (gain in $dB = 10 \log_{10} (P_o/P_i)$.

Q10. The maximum frequency for reflection of sky waves from a certain layer of the ionosphere is found to be $f_{max} = 9 (N_{max})^{1/2}$, where N_{max} is the maximum electron density at that layer of the ionosphere. On a certain day it is observed that signals of frequencies higher than 5 MHz are not received by reflection from the F_1 layer of the ionosphere while signals of frequencies higher than 8 MHz are not received by reflection from the F_2 layer of the ionosphere. Estimate the maximum electron densities of the F_1 and F_2 layers on that day.

Q11. If the whole Earth is to be connected by LOS communication using space waves (no restriction of antenna size or tower height), what is the minimum number of antennas required? Calculate the tower height of these antennas in terms of Earths radius?

Q12. A 50 MHz sky wave takes 4.04 ms to reach a receiver via re-transmission from a satellite 600 km above earth's surface. Assuming re-transmission time by satellite negligible, find the distance between source and receiver. If communication between the two was to be done by Line of Sight (LOS) method, what should size and placement of receiving and transmitting antenna be?

Q13. An amplitude modulated wave is as shown in figure. Calculate

(a) the percentage modulation,

(b) peak carrier voltage and,

(c) peak value of information voltage.

Q14. An audio signal is modulated by a carrier wave of 20 MHz such that the bandwidth required for modulation is 3 kHz. Could this wave be demodulated by a diode detector which has the values of R and C as:

(a) $R = 1\ k\Omega$, $C = 0.01\ \mu F$. (b) $R = 10\ k\Omega$, $C = 0.01\ \mu F$. (c) $R = 10\ k\Omega$, $C = 0.1\ \mu F$.

Q15. (a) Draw the plot of amplitude versus 'ω' for an amplitude modulated wave whose carrier wave (ω_c) is carrying two modulating signals, ω_1 and ω_2 ($\omega_2 > \omega_1$).

(b) Is the plot symmetrical about ω_c? Comment especially about plot in region $\omega < \omega_c$.

(c) Extrapolate and predict the problems one can expect if more waves are to be modulated.

(d) Suggest solutions to the above problem. In the process can one understand another advantage of modulation in terms of bandwidth?

Q16. (a) The intensity of a light pulse travelling along a communication channel decreases exponentially with distance x according to the relation $I = I_0 e^{-\alpha x}$, where I_0 is the intensity at x = 0 and α is the attenuation constant.

Show that the intensity reduces by 75 per cent after a distance of $\left(\frac{\ln 4}{\alpha}\right)$.

(b) Attenuation of a signal can be expressed in decibel (dB) according to the relation dB $= 10 \log_{10}\left(\frac{I}{I_0}\right)$. What is the attenuation in dB/km for an optical fibre in which the intensity falls by 50 per cent over a distance of 50 km?

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S1. Let A_c and A_m be the amplitudes of carrier wave and modulating wave respectively. So,

$$\text{Maximum amplitude} \longrightarrow A_{max} = A_c + A_m = 15\,\text{V} \quad \ldots \text{(i)}$$

$$\text{Minimum amplitude} \longrightarrow A_{min} = A_c - A_m = 3\,\text{V} \quad \ldots \text{(ii)}$$

Adding Eq. (i) and (ii), we get

$$2A_c = 18$$

or $$A_c = 9\,\text{V}$$

and $$A_m = 15 - 9 = 6\,\text{V}$$

Modulating index of wave $\mu = \dfrac{A_m}{A_c} = \dfrac{6}{9} = \dfrac{2}{3}$.

S2. No, signals of frequency greater than 30 MHz will not be reflected by the ionosphere, but will penetrate through the ionosphere and transmission is not possible.

S3. The refractive index increases with increase in frequency which implies that for higher frequency waves, angle of refraction is less, *i.e.*, bending is less. Hence, the condition of total internal reflection is attained after travelling larger distance (by 3 MHz wave).

S4.

$$\frac{1}{2\pi\sqrt{LC}} = 1\,\text{MHz}$$

$$\sqrt{LC} = \frac{1}{2\pi \times 10^6}.$$

S5. In Amplitude modulation (AM), the carrier waves instantaneous voltage is varied by modulating waves voltage. On transmission, noise signals can also be added and receiver assumes noise a part of the modulating signal.

However in Frequency modulation (FM), the carriers frequency is changed as per modulating waves instantaneous voltage. This can only be done at the mixing/ modulating stage and not while signal is transmitting in channel. Hence, noise doesn't effect FM signal.

S6. (a) analog (b) analog (c) digital (d) digital

S7. Given, Hight of antenna $h = 20$ m

Radius of Earth $= 64 \times 10^6$ m

At the ground level,

(a) $$\text{Range} = \sqrt{2hR} = \sqrt{2 \times 6.4 \times 10^6 \times 20} = 16\text{ km}$$

Area covered $= 803.84\,\text{km}^2$

(b) At a height of H = 25 m from ground level

$$\text{Range} = \sqrt{2hR} + \sqrt{2HR}$$

$$= \sqrt{2 \times 6.4 \times 10^6 \times 20} + \sqrt{2 \times 6.4 \times 10^6 \times 25}$$

$$= (16 + 17.9)\ \text{km} = 33.9\ \text{km}$$

$$\text{Area covered} = \pi\,(\text{Range})^2 = 3608.52\ \text{km}^2$$

∴ Percentage increase in area

$$= \frac{(3608.52 - 803.84)}{803.84} \times 100 = 348.9\%.$$

S8. In amplitude modulated signal, only side band frequencies contain information. Thus only $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$ contain information.

Now, according to question, the total radiated power is due to energy carried by

$$\omega_c,\ (\omega_c - \omega_m) \quad \text{and} \quad (\omega_c + \omega_m).$$

Thus to minimise the cost of radiation without compromising on information ω_c can be left and transmitting. $(\omega_c + \omega_m)$, $(\omega_c - \omega_m)$ or both $(\omega_c + \omega_m)$ and $(\omega_c - \omega_m)$.

S9. Loss suffered in transmission path

$$= -2\ \text{dB km}^{-1} \times 5\ \text{km} = -10\ \text{dB}$$

$$\text{Total amplifier gain} = 10\ \text{dB} + 20\ \text{dB}$$

$$= 30\ \text{dB}$$

$$\text{Overall gain of signal} = 30\ \text{dB} - 10\ \text{dB}$$

$$= 20\ \text{dB}$$

$$10 \log\left(\frac{P_o}{P_i}\right) = 12 \quad \text{or} \quad P_o = P_i \times 10^2$$

$$= 1.01\ \text{mW} \times 100 = 101\ \text{mW}.$$

S10. The maximum frequency for reflection of sky waves

$$f_{\max} = 9\,(N_{\max})^{1/2}$$

where, $N_{\max}$ is a maximum electron density.

For F_1 layer $\quad 5 \times 10^6 = 9\,(N_{\max})^{1/2}$

or $\quad N_{\max} = \left(\frac{5}{9} \times 10^6\right)^2 = 3.086 \times 10^{11}\ \text{m}^{-3}$

For F_2 layer $\quad 8 \times 10^6 = 9\,(N_{\max})^{1/2}$

or $\quad N_{\max} = \left(\frac{8}{9} \times 10^6\right) = 7.9 \times 10^{11}\ \text{m}^{-3}.$

S11.

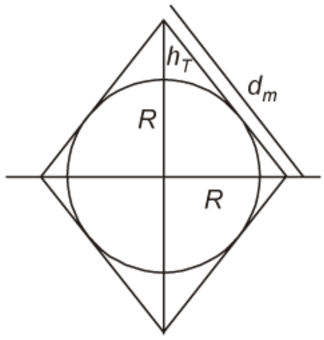
$$d_m^2 = 2(R + h_T)^2$$

$$8\,Rh_T = 2(R + h_T)^2 \qquad (\because\ d_m = 2\sqrt{2Rh_T})$$

$$4\,Rh_T = R^2 + h_T^2 + 2\,Rh_T$$

$$(R - h_T)^2 = 0$$

$$R = h_T$$



Since space wave frequency is used, $\lambda << h_T$, hence only tower height is taken to consideration.

In three dimensions, 6 antenna towers of $h_T = R$ would do.

S12. Let the receiver is at point *A* and source is at *B*.

Velocity of waves = 3×10^8 m/s

Time to reach a receiver = 4.04 ms = 4.04×10^{-3} s

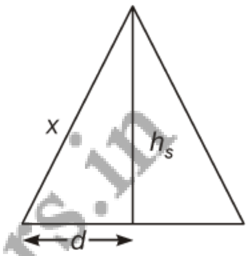
Let the height of satellite is h_s = 600 km

Radius of Earth = 6400 km

Height of transmitting antenna = h_T

We know that

$$\frac{\text{Distance travelled by wave}}{\text{Time}} = \text{Velocity of waves}$$



$$\frac{2x}{\text{time}} = \text{velocity}$$

$$2x = 3 \times 10^8\ \text{m/s} \times 4.04 \times 10^{-3}\ \text{s}$$

$$x = \frac{12.12 \times 10^5}{2}\ \text{m} = 6.06 \times 10^5\ \text{m} = 606\ \text{km}$$

$$d^2 = x^2 - h_s^2 = (606)^2 - (600)^2 = 7236;\ d = 85.06\ \text{km}$$

Distance between source and receiver = $2d \cong 170$ km

$$d_m = 2\sqrt{2Rh_T},\ 2d = d_m,\ 4d^2 = 8\,Rh_T$$

$$\frac{d^2}{2R} = h_T = \frac{7236}{2 \times 6400} \approx 0.565\ \text{km} = 565\ \text{m}.$$

S13. From the figure

$$V_{\max} = \frac{100}{2} = 50\ \text{V}, \quad V_{\min} = \frac{20}{2} = 10\ \text{V}.$$

(a) Percentage modulation

$$\mu\,(\%) = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} \times 100 = \left(\frac{50 - 10}{50 + 10}\right) \times 100$$

$$= \frac{40}{60} \times 100 = 66.67\%$$

(b) Peak carrier voltage = $V_c = \frac{V_{max} + V_{min}}{2} = \frac{50+10}{2} = 30\,V.$

(c) Peak information voltage = $V_m = \mu V_c = \frac{2}{3} \times 30 = 20\,V.$

S14. Loss suffered in transmission path

$$= -2\,dB\,km^{-1} \times 5\,km = -10\,dB$$

$$\text{Total amplifier gain} = 10\,dB + 20\,dB = 30\,dB$$

$$\text{Overall gain of signal} = 30\,dB - 10\,dB = 20\,dB$$

$$10 \log\left(\frac{P_o}{P_i}\right) = 12 \quad \text{or} \quad P_o = P_i \times 10^2$$

$$= 1.01\,mW \times 100 = 101\,mW.$$

S15. (a)

$$v(t) = A(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_{m_2} t + A_c \sin \omega_c t) + B(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_{m_2} t + A_c \sin \omega_c t)^2$$

$$= A(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_{m_2} t + A_c \sin \omega_c t) + B[(A_{m_1} \sin \omega_{m_1} t + A_{m_2} t)^2 + A_c^2 \sin^2 \omega_c t + 2A_c(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_c t)]$$

$$= A(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_{m_2} t + A_c \sin \omega_c t) + B[(A_{m_1}^2 \sin^2 \omega_{m_1} t + A_{m_2}^2 \sin^2 \omega_{m_2} t + 2A_{m_1} A_{m_1} \sin \omega_{m_1} t \sin \omega_{m_2} t + A_c^2 \sin^2 \omega_c t + 2A_c(A_{m_1} \sin \omega_{m_1} t \sin \omega_c t + A_{m_2} \sin \omega_{m_2} + \sin \omega_c t)]$$

$$= A(A_{m_1} \sin \omega_{m_1} t + A_{m_2} \sin \omega_{m_2} t + A_c \sin \omega_c t) \sin + B[(A_{m_1}^2 \sin^2 \omega_{m_1} t + A_{m_2}^2 \sin^2 \omega_{m_2} t + A_c^2 \sin^2 \omega_c t$$

$$+ \frac{\cancel{2} A_{m_1} A_{m_2}}{\cancel{2}} [\cos(\omega_{m_2} - \omega_{m_1}) t - \cos(\omega_{m_1} + \omega_{m_2}) t]$$

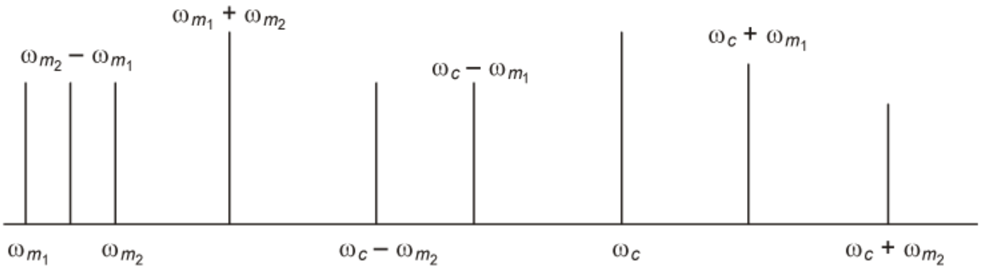
$$+ \frac{\cancel{2} A_c A_{m_2}}{\cancel{2}} [\cos(\omega_c - \omega_{m_1}) t - \cos(\omega_c + \omega_{m_1}) t]$$

$$+ \frac{\cancel{2} A_c A_{m_1}}{\cancel{2}} [\cos(\omega_c - \omega_{m_2}) t - \cos(\omega_c + \omega_{m_2}) t]$$

$\therefore$ Frequencies present are:

$$\omega_{m_1}, \omega_{m_2}, \omega_c$$
$$(\omega_{m_2} - \omega_{m_1}), (\omega_{m_1} + \omega_{m_2})$$
$$(\omega_c - \omega_{m_1}), (\omega_c + \omega_{m_1})$$
$$(\omega_c - \omega_{m_2}), (\omega_c + \omega_{m_2})$$

(i) Plot of amplitude versus ω is shown in the Figure.



(ii) As can be seen frequency spectrum is not symmetrical about ω_c. Crowding of spectrum is present for $\omega < \omega_c$.

(iii) Adding more modulating signals lead to more crowding in $\omega < \omega_c$ and more chances of mixing of signals.

(iv) Increase band-width and wc to accommodate more signals. This shows that large carrier frequency enables to carry more information (more wm) and which will in turn increase bandwidth.

S16. (a) Given, the intensity of light pulse $I = I_0 e^{-\alpha x}$

where, I_0 is the intensity at $x = 0$ and α is constant.

According to the question, I = 25% of $I_0 = \frac{25}{100} \cdot I_0 = \frac{I_0}{4}$

Using the formula mentioned in the question,

$$I = I_0 e^{-\alpha x}$$

$$\frac{I_0}{4} = I_0 e^{-\alpha x}$$

or $$\frac{1}{4} = e^{-\alpha x}$$

Taking log on both sides, we get

$$\ln 1 - \ln 4 = -\alpha x \ln e$$

$$-\ln 4 = -\alpha x$$

$$x = \frac{\ln 4}{\alpha}$$

Therefore, at distance $x = \frac{\ln 4}{\alpha}$, the intensity is reduced to 75% of initial intensity.

(b) Let α be the attenuation in dB/km. If x is the distance travelled by signal, then

$$10 \log_{10} \left(\frac{I}{I_0}\right) = -\alpha x \quad \text{... (i)}$$

where, I_0 is the intensity initially,

According to the question, I = 50% of $I = \frac{I_0}{2}$ and x = 50 km

Putting the value of x in Eq. (i), we get

$$10 \log \left(\frac{1}{2}\right) = -50\alpha \quad \text{or} \quad \log 2 = 5\alpha$$

or $$\alpha = \frac{\log 2}{5} = \frac{0.3010}{5} = 0.0602 \text{ B/km}.$$